THE OCULAR ADNEXA AND LACRIMAL APPARATUS

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CHAPTER CONTENTS

INTRODUCTION

The ocular adnexa includes all structures situated in close proximity to the eyeballs. This chapter will concentrate on the eyelids and lacrimal apparatus through which tears drain.

FUNCTIONS OF EYELIDS

Eyelids have four main functions:

i. Protection of the globe from both light and mechanical damage

ii. Production of different tear components

iii. Distribution of the tear film across the anterior surface.

iv. Distribution of tears, especially towards the drainage area at the medial canthus

EXTERNAL LANDMARKS

(See Figure 7.1):

Palpebral aperture: opening between lids.

Canthus: the angle on medial and lateral sides of the palpebral aperture

Superior palpebral sulcus: divides orbital and tarsal part of eyelid.

Eyebrow: marks the upper bound of the orbital eyelid. It serves to prevent moisture entering the palpebral aperture and is very important in facial expression.

Epicanthus: a medial fold occluding part of sclera

Caruncle: a small pad of tissue separating eyelids on medial side. It contains sweat and sebaceous glands and serves to trap foreign particles.

Plica Semilunaris: a small fold of bulbar conjunctiva on the medial canthus of the eye.

Punctum, (plural = puncta): entrance to nasolacrimal drainage system small orifice on papilla lacrimali

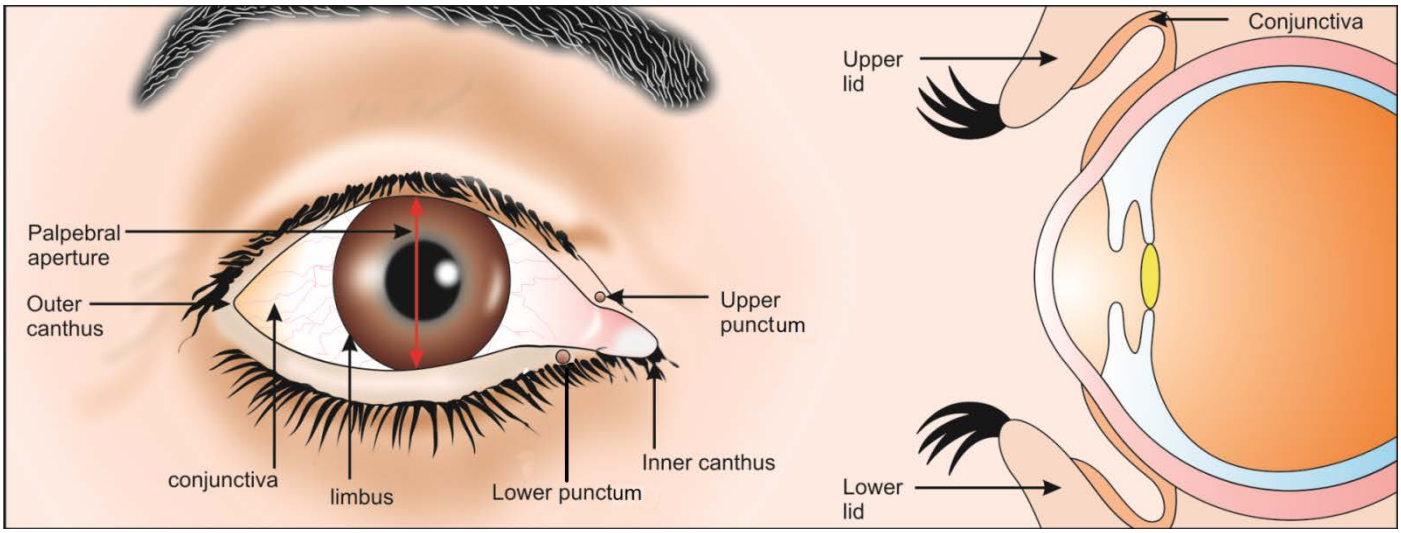

Figure 7.1: *Features of outer eyelids*

EYELID TOPOGRAPHY

The upper eyelid extends to the eyebrow and includes a tarsal and an orbital part. The tarsal portion of the eyelid is that part which covers the globe, and contains the tarsal plate. The orbital portion extends from the tarsus to the eyebrow, and is separated from the tarsal portion by a furrow called the superior palpebral sulcus.

HISTOLOGICAL STRUCTURE OF THE UPPER EYELID

Histologically, the upper eyelid contains:

- very thin skin,
- muscle,
- tarsal plate,
- conjunctiva and
- a series of glands (see figure 7.2).

Below, we discuss each of these components in turn.

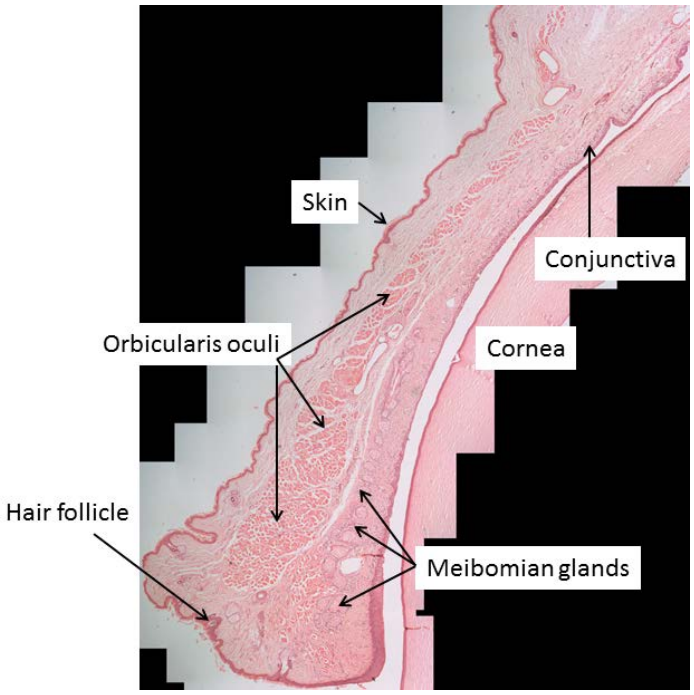

Figure 7.2: *Vertical section of upper eyelid*

1. SKIN

The skin of the eyelid is similar to the skin on the rest of body but it is very thin, which aids folding during rapid opening and closing. It is loosely attached to the underlying muscle, creating a potential space which is easily filled by blood (from a haemorrhage) or lymph (in oedema). It contains the eyelashes, arranged in 2-3 rows, on the upper and lower lid margins (approx. 150 upper, 75 lower). These have a lifespan of 3-5 months but display fast regeneration. Three sets of glands are found around the eyelid margin; two of these are sebaceous and include the *Glands of Zeiss,* which empty into the lash follicles, and the Meibomian glands that extend from the lid margin up into the tarsal plate of the eye lid. These glands produce the outermost oily layer of the tear film. The third set of

glands are the Glands of Moll which are modified apocrine sweat glands found in between the lash follicles. The eyelashes play an important sensory role in detecting small foreign bodies and touch by external objects. Sensory innervation comes from the trigeminal (Vth) nerve via a nerve plexus surrounding each follicle.

Skin contains an epidermal layer overlying a dermis that is abundant in elastic fibres. A very sparse connective tissue layer, subcutaneous tissue, is found below the dermis. In the tarsal portion of the eyelid, this subcutaneous layer is devoid of adipose tissue, whereas in the orbital portion, there is a fat pad that separates the orbicularis oculi from the skin.

2. MUSCLES OF THE EYE LID:

(i) Obicularis oculi (OO)

The orbicularis oculi is located deep within the subcutaneous layer and consists of striated muscle fibres. In the cross-sectional view shown in Figure 7.3a, the fibres that form the orbicularis are cut in cross section, and hence can be seen as pink “circles” (Figure 7.3a).

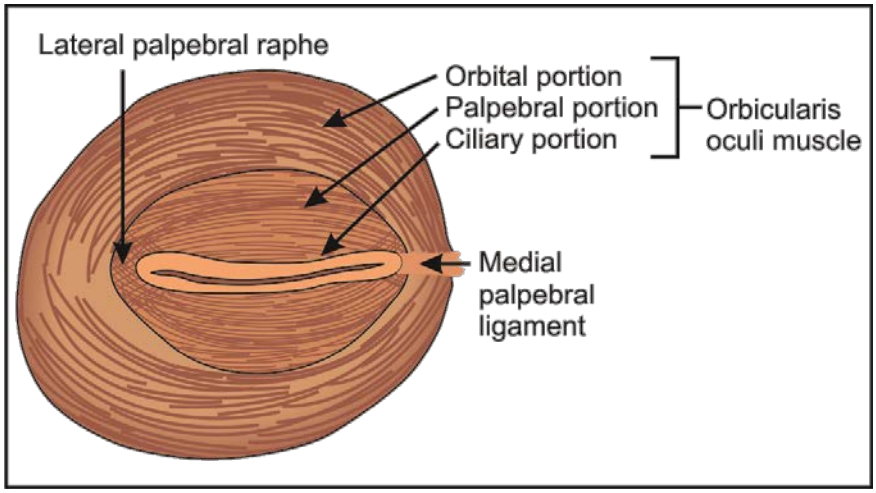

Figure 7.3(a): Orbicularis oculi muscle

The orbicularis arises from the medial palpebral ligament (MPL) on the nasal side and sweep concentrically around the lids.

It is innervated by the *temporal* and *zygomatic* branches of facial nerve and can be divided into 3 (non-distinct) parts:

Orbital portion

This is the portion overlying the extraorbital bones. It surrounds orbital margin and, on contraction, closes like purse-string anchored at the MPL. It is involved mainly in voluntary action such as forced and tight closure of the eyelid of the eyes to exclude bright light or in other facial expressions.

Palpebral portion

The *palpebral* (eyelid) part of OO produces both voluntary closure, such as winking, and involuntary blinking, as in sensory reflex and spontaneous blinking. Spontaneous blinking is infrequent during the first few months of life. Blink rate averages at around 10-15 times per minute in the adult, but varies enormously between individuals and their situation (e.g. lower during reading or conversation). It is preserved in persons who are blind and thus is not dependent on retinal light stimulation.

The palpebral eyelid can be divided into two further portions:

Preseptal portion

This is the superior palpebral portion. Fibres run from the medial palpebral ligament on the nasal side to the *lateral palpebral raphe* on temporal side (see Figure 7.3a).

Pretarsal portion

This is the inferior palpebral portion. Fibres here are straighter than in the preseptal portion and pull the eyelid medially on contraction.

Lacrimal portion

It extends behind lacrimal sac (Figure 7.3b). It possibly provides a pumping mechanism for tears during blink: pressure on the lacrimal sac expels tears downwards into the nasolacrimal duct; the vacuum that follows draws further tears into the sac. OO muscle fibres at the lid margin are sometimes referred to as the ciliary portion. On blinking the eyelid margin closes in a zipper-like fashion from lateral to medial canthus aiding propelling tears towards the puncta.

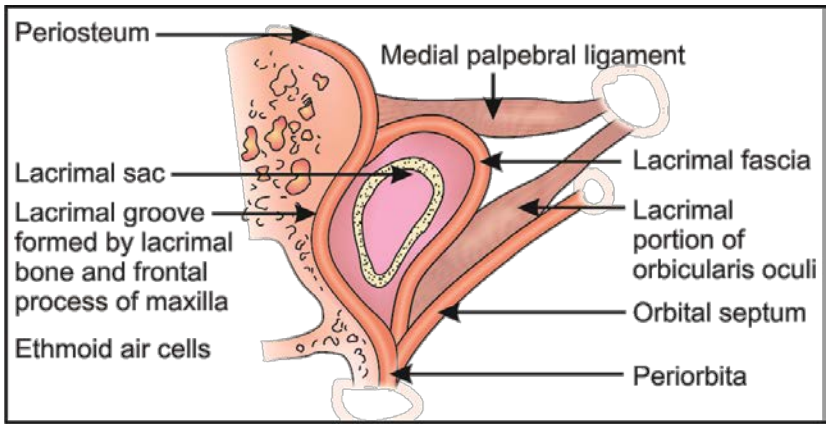

Figure 7.3(b): Lacrimal sac portion

ii) Levator palpebrae superioris and Muller's muscle

Orbital septum (OS) is a membraneous sheet extending across the palpebral portions of both the upper and lower eyelid (Figure 7.4). It is continuous with the periorbita at the orbital margin, is perforated by the *aponeurosis* (fan-like tendon) of the *levator palpebrae superioris*, and inserts into the distal tarsal plate. Innervated by the superior division of cranial nerve III (oculomotor) the larger (upper) portion of the levator serves to raise the upper lid in a mainly *voluntary* fashion. Tonus of the levator has an effect on the size of the palpebral aperture.

The tarsal muscle (Muller's muscle) is composed of smooth muscle and originates on the posterio-inferior portion of the levator palpebrae superioris. Its function is thought to enhance elevation. Innervated by sympathetic fibres from superior cervical ganglion (i.e. not cranial) it increases the palpebral aperture during a 'fight or flight' response (i.e. in fear or surprise). Being innervated by a more minor division, interruption of neural supply to Muller's muscle results in incomplete ptosis, as seen in Horner's syndrome.

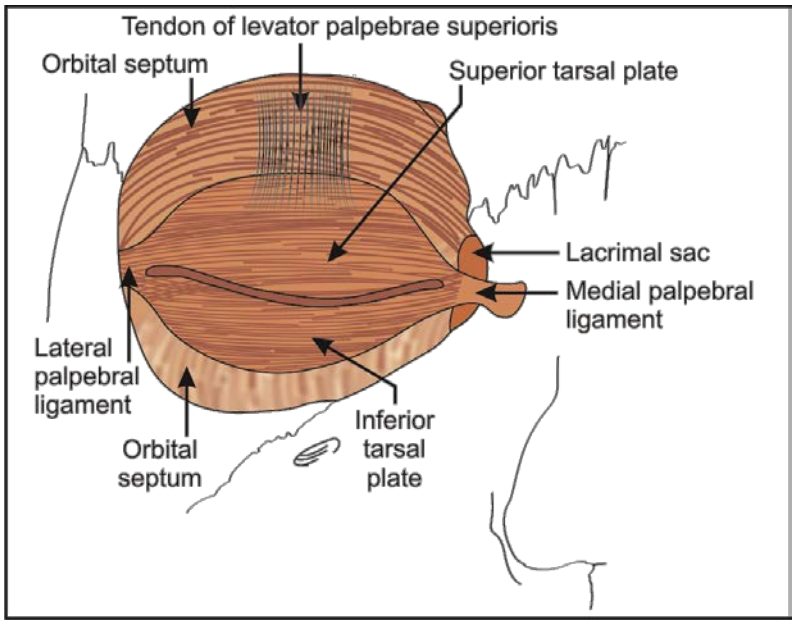

Figure 7.4: *Orbital septum, tarsal plate and levator superioris*

3. TARSAL PLATE

Embryologically an extension and thickening of the orbital septum, the *tarsal plate* provides rigidity to the lids. The tarsal plate is attached to the *medial palpebral ligament* nasally and a *lateral palpebral ligament* temporally. The tarsal plate contains tarsal (*meibomian*) glands (Figure 7.5), the ducts of which are arranged in a row along the eyelid margin (30 top lid and 20 bottom lid). As modified sebaceous glands composed of numerous acini, they produce the largest oily (sebaceous) component of the tears and are important for tear stability.

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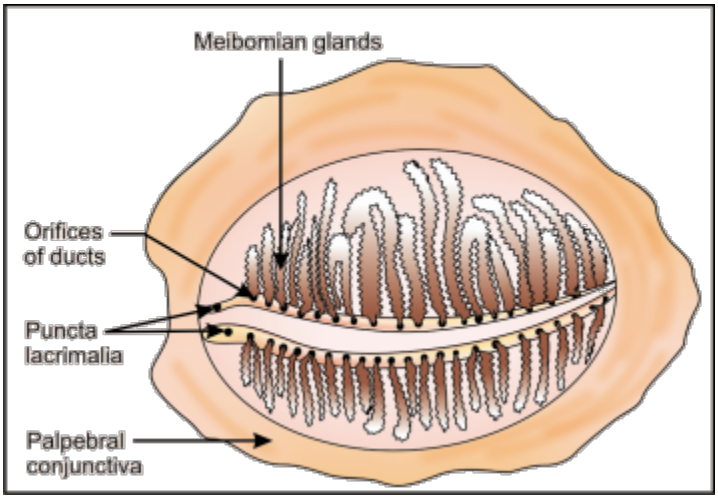

Figure 7.5: *Tarsal plate containing meibomian glands*

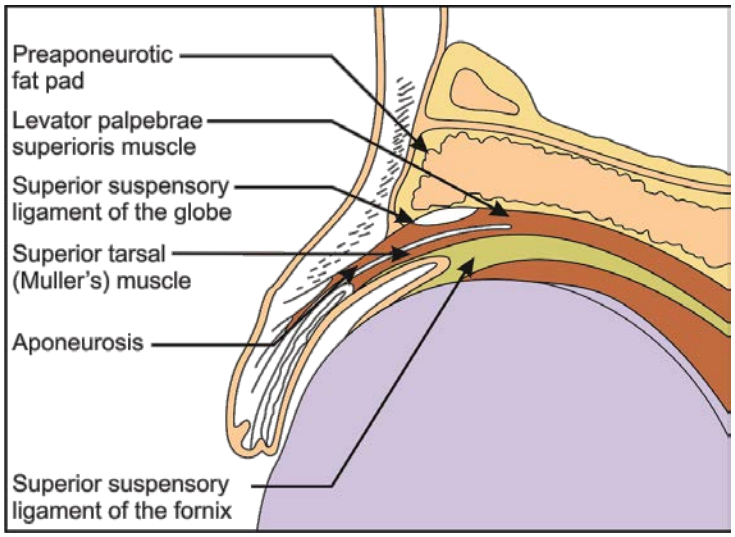

Figure 7.6: *Superior portion of the tarsal plate*

4. CONJUNCTIVA

The conjunctiva is a mucous membrane covering the posterior surface of the lids and the anterior one-third of the globe and can be divided into *tarsal* (or palpebral) and *bulbar* sections. The two parts are divided superiorly and inferiorly by the upper and lower *fornices* (singular *fornix*). The conjunctiva fuses with the sclera at the corneoscleral junction (limbus), its epithelium being continuous with that of the corneal epithelium. The Palisades of Vogt are found at the limbus and appear as radial ridges of about 1.5-2mm in length. The epithelial layer contains unicellular glands termed *goblet cells* which secrete the basal mucous layer of the tear film (Figure 7.7).

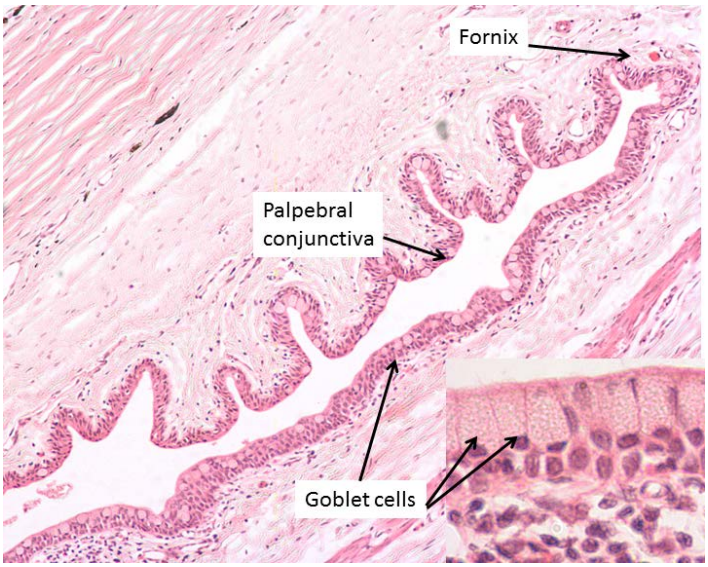

Figure 7.7 *Cross section of the palpebral and bulbar conjunctiva. Numerous goblet cells can be seen in this part of the conjunctiva.*

5. GLANDS OF THE EYELID

The main glands of the eyelid include the meibomian glands, which are sebaceous glands embedded within the tarsal plate. These are long multilobed glands that are arranged vertically, with openings located in a row on the eyelid margin, just posterior to the cilia.

The sebaceous glands of Zeiss are associated with the hair follicles and secrete sebum into the hair follicle to prevent them from becoming too brittle.

The glands of Moll are modified sweat glands located near the lid margin. Their ducts empty into the hair follicle, into the Zeis gland duct, or directly onto the lid margin.

The accessory glands of Kraus are located in the stroma of the conjunctival fornix. The accessory glands of Wolfring are located along the orbital border of the tarsal plate. These two accessory glands (accessory to the lacrimal gland) are thought to secrete a substance that is similar to the main lacrimal gland, and contributes to the aqueous layer of the tear film.

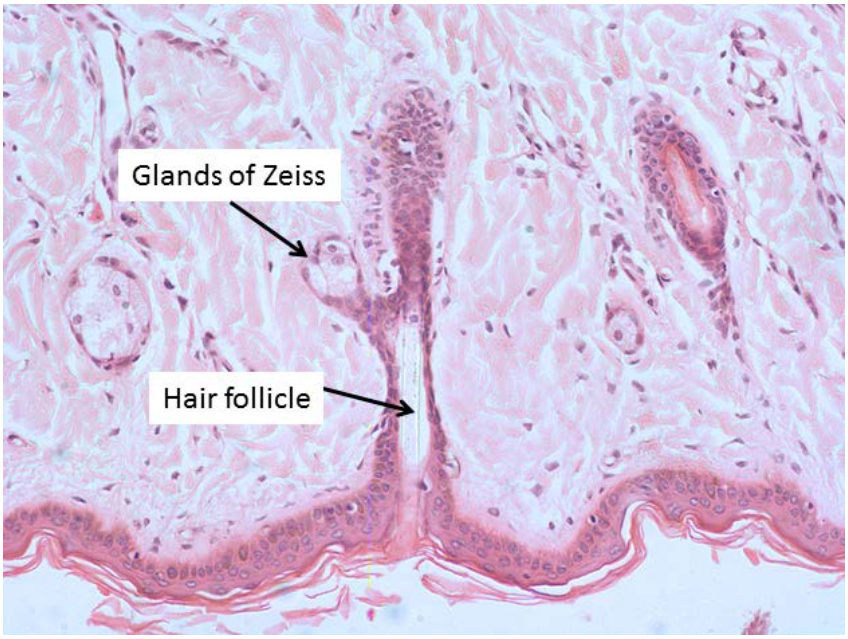

Figure 7.8 *Cross section of the eyelid showing a gland of Zeiss associated with a hair follicle.*

THE LOWER LID

The lower eyelid is a smaller, inverted version of the upper but contains no equivalent of the levator. It is much less mobile, moving only slightly on opening and closure, and tends to increasingly sag with age.

BLOOD SUPPLY TO THE EYELIDS

The various arteries supplying blood to the eyelids are principally branches of the ophthalmic artery. The conjunctival blood supply is via the posterior palpebral arteries which derive from the palpebral arterial arcades and reach backwards across the fornix and over the bulbar conjunctiva as far as the limbus, where they anastomose with the anterior ciliary arteries.

Venous drainage from both tarsal and other conjunctival regions is via divisions of the ophthalmic veins to the angular and superficial temporal veins.

THE LACRIMAL GLAND

Lodged in a depression in the frontal bone (called the lacrimal fossa) and located on the superior lateral aspect of the orbit (Figure 7.9), the lacrimal gland is an almond-shaped gland and is composed of two portions: the superior *orbital* portion and the inferior *palpebral* portion, partially separated by the aponeurosis of the levator palpebrae superioris.

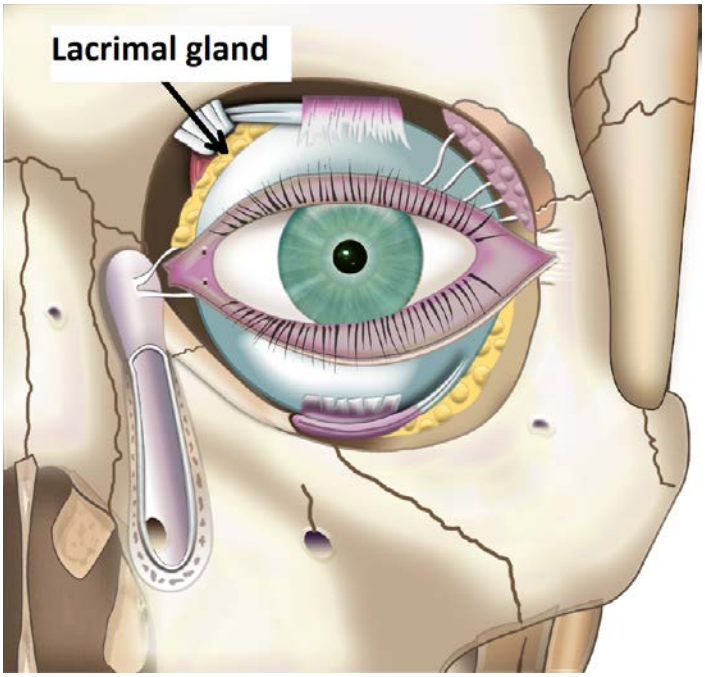

Figure 7.9: *Lacrimal gland Image from http://www.d.umn.edu/~jfitzake/Lectures/DMED/Vision/Optics/Crying.html*

STRUCTURE OF THE LACRIMAL GLAND

The gland consists of masses of acini (lobules) each about the size of a pin-head. Each acinus has two layers of cells. The outer layer cells are myoepithelial in type and flat in appearance. The inner cells are cylindrical, contain secretory granules, and are the main secreting cells.

Secretions from the lobules pass into small connecting ducts, then into larger ducts and finally into 10-12 excretory ducts which open into the conjunctival sac at the upper fornix, below the aponeurosis of the levator palpebrae superioris.

BLOOD SUPPLY

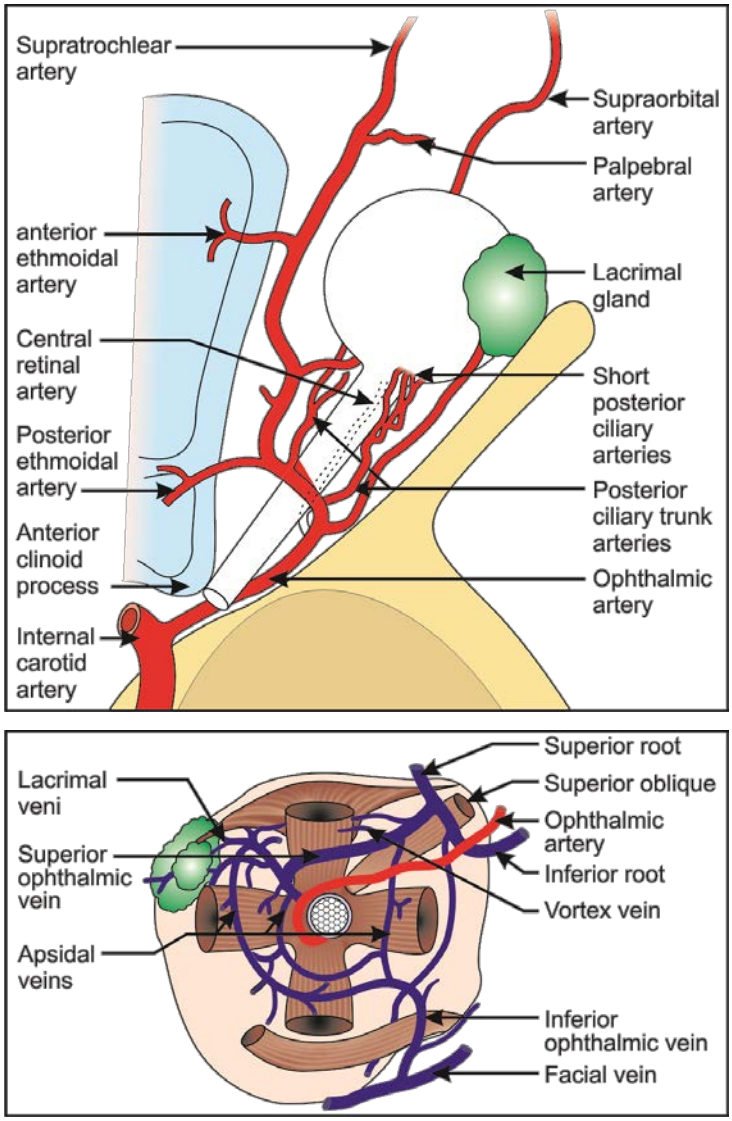

Figure 7.10: *Blood supply to lacrimal gland*

Blood supply (Figure 7.10) to the lacrimal gland is via the *lacrimal artery* (a branch of the ophthalmic artery) which runs along the superior border of the lateral rectus muscle and enters the gland by its posterior border. Drainage is via the *lacrimal vein* which joins the superior ophthalmic vein.

INNERVATION

Parasympathetic control:

Reflex tearing is regulated by afferent and efferent innervation.

Afferent – Fibres from the secretory centre in the pons pass via the *lacrimal nerve*, a division of the ophthalmic branch of the trigeminal (V), to the lacrimal gland.

Efferent – Fibres from facial nerve (VII) pass through facial ganglion to the pterygonopalatine ganglion where they synapse. From there fibres from the ganglion join the Zygomatic nerve, (a branch of the maxillary division of the

trigeminal nerve V) to enter the orbit, and pass as a communicating branch to the lacrimal nerve (a branch of the ophthalmic division of the Trigeminal nerve V) which conveys them to the lacrimal gland.

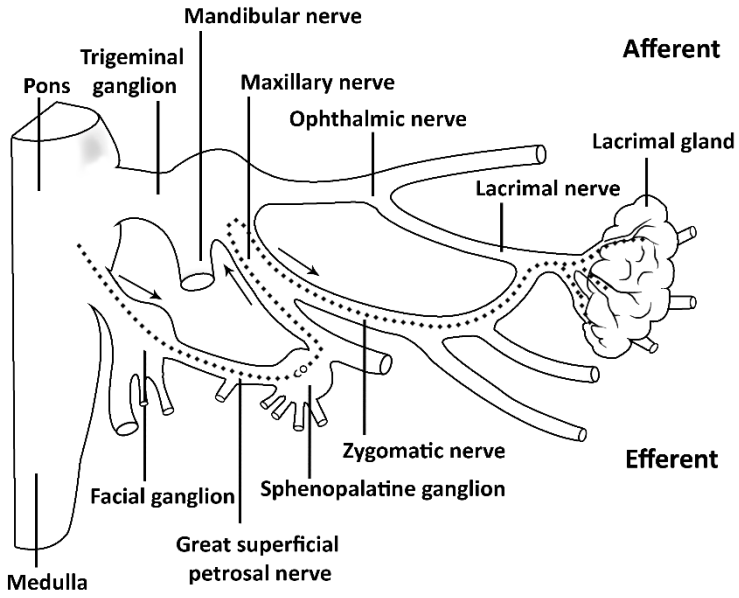

Figure 7.11: *Nerve innervation in lacrimal gland*

Sympathetic control:

Fibres from hypothalamus pass via the superior cervical ganglion to reach the lacrimal gland by the greater petrosal nerve.

TEAR PRODUCTION

The tears form a thin film over the cornea and conjunctiva and a tear meniscus, or prism, can be observed at the lower lid margin. The tear film is actually an emulsion but is most conveniently described as having three layers (Figure 7.12).

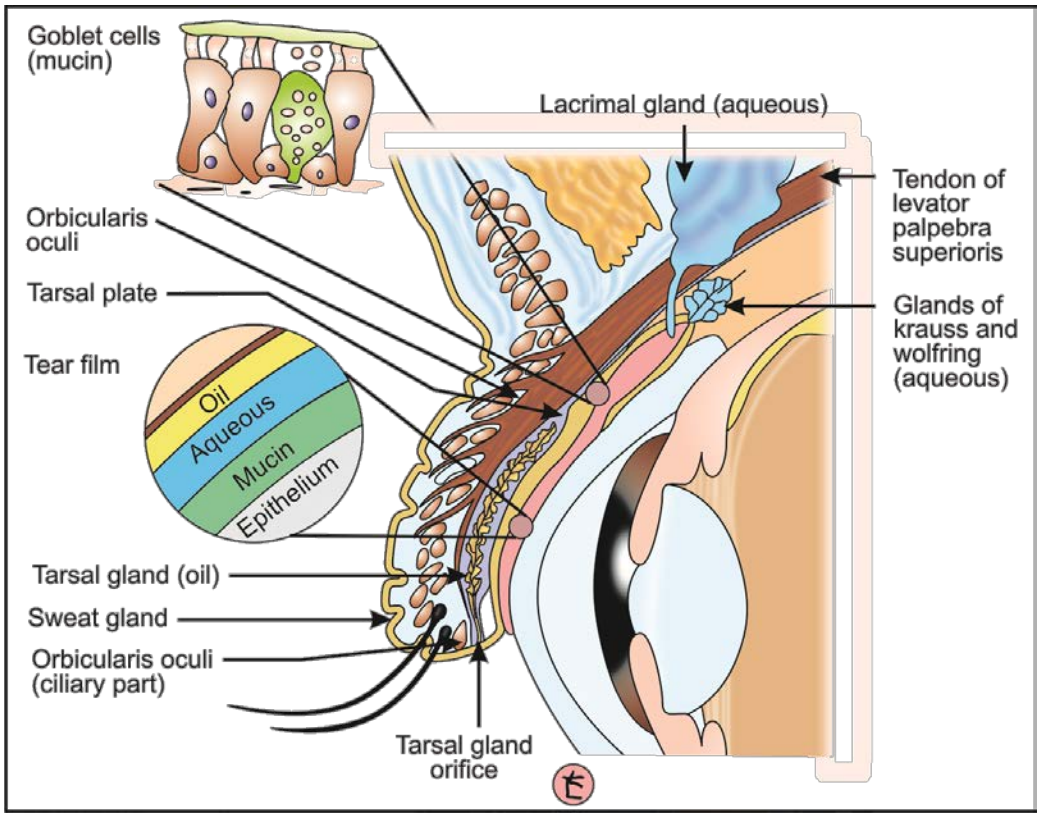

Figure 7.12: *Tear glands and layers*

i. The oily *lipid layer* of the tears is the outermost layer. Composed mainly of cholesterol, fatty acids and phospholipids, it is produced by the *meibomian glands* in the tarsal plate and the *glands of Zeiss* at the eyelid margin. This layer is important for tear stability in that it helps reduce evaporation of the aqueous component and prevents overflow at the lower lid margin. Deficiencies in the lipid layer can result from contact lens wear or meibomian gland blockage.

ii. The middle *aqueous layer* is by far the thickest layer (7-8μ), and is secreted by the lacrimal gland along with the *Accessory Lacrimal Glands of Krause*, found in upper *conjunctival* fornix and *Wolfring* in the superior portion of the palpebral conjunctiva. The aqueous layer contains various water-soluble proteins (mostly albumin), salts, glucose and lactate. Secretions from the lacrimal gland contain antibacterial proteins such as lysozyme and lactoferrin, immunoglobulin A and beta-lysin. The aqueous layer also helps to improve optical quality by smoothing out irregularities of the cornea.

iii. The basal, *mucin layer* is produced by the *goblet cells* of the conjunctiva (Figure 7.7). It is in contact with the cornea where it is held by the microvillae of the corneal epithelial cells and thus is not totally swept away during blinking. The mucin layer improves the hydrophilic nature, and thus wetting properties, of the cornea. Reasons for mucin layer deficiency include Vitamin A deficiency and the destruction of goblet cells in conditions like trachoma.

Normal tear production is primarily under sympathetic control. While both the lacrimal and accessory lacrimal glands contribute to the aqueous tear component, excision of the lacrimal gland has shown that normal aqueous tear production can be adequately dealt with by the accessory lacrimal system. The lacrimal gland comes into its own, however, when large quantities of fluid are required very quickly during reflex tearing. Reflex tearing can arise from peripheral sensory stimulation (Vth nerve through the skin, cornea, conjunctiva or nose) or central sensory stimulation such as retinal light stimulation or emotional crying.

Tear production can be crudely measured by the *Schirmer test*. Mucous layer deficiencies can be evaluated by tear film break-up-time (TBUT).

Tear drainage

Approx. 25% of tears lost through evaporation, depending on blink-rate, atmosphere, climate and the individual. The remainder leaves eye through nasolacrimal drainage system (Figure 7.13) by the following forces:

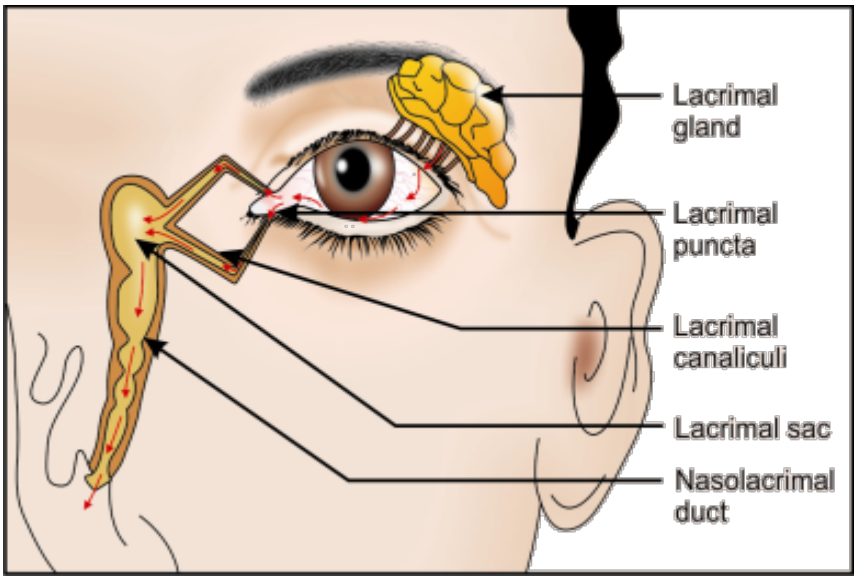

Figure 7.13: *Tear flow*

i. *Gravity* conveys tears from upper fornix to form lower tear *prism*.

ii. *Lid movement* on blinking conveys tears towards the *puncta* on the nasal side (the lids close in a zipper-like fashion from temporal to nasal side because the obicularis muscle is more firmly attached on the nasal side).

iii. *Capillary attraction* by the *canaliculi,* small tubules of about 10mm length extending from the puncta to the *lacrimal sac*, also helps draw tears into the *punctum*.

iv. *Squeezing of the lacrimal sac* by the lacrimal portion of the obicularis during lid closure forces fluid into the *nasolacrimal duct*. The removal of pressure on opening then creates a vacuum which draws fluid along the canaliculi.

Each blink also serves to re-establish the tear film layers following any break-up. Normal blink rate can vary from around 25/min during conversation to only 3-4/min during reading or computer use.

From the lacrimal sac (which sits on the lacrimal fossa), tears drain into the *naso-lacrimal duc*t (NLD), a 15mm-long tube that runs down through the *lacrimal canal*. From the NLD the tears drain into the inferior nasal meatus where they largely evaporate, aided by the movement of air during breathing.